Journal of Energy in Southern Africa 19(1): 55–61
DOI: http://dx.doi.org/10.17159/2413-3051/2008/v19i1a3318

Contribution analysis of electrical energy management in the industrial and commercial sector: a challenge to the Tanzania utility industry

A K Mohamed

M T E Kahn

Centre for Distributed Power Electronic Systems, Department of Electrical Engineering, Cape Peninsula University of Technology, Bellville, South Africa

Abstract

The investigation of electrical energy management (EEM) in the industrial and commercial sector determines how energy management affects electricity consumption and what makes its potential for being used to reduce peak demand of utility industries. The aim of this paper is to analyze the contribution of electrical energy management in the industrial and commercial sector and highlight its challenges to the Tanzanian utility industry. Energy efficiency technology analyzed in this paper includes energy efficiency lighting and power factor improvement. The analysis found that, if EEM is properly implemented, a significant amount of energy could be saved and could be converted to monetary benefits which might facilitate the development of other activities. The utility industry can benefit from saving considerable amounts of energy as well as the reduction of peak demand which can minimize the race of stumbling on new energy sources and construction of new power plants. The saved energy can be distributed to other consumers so as to improve accessibility or reliability of the electrical system and consequently minimize the impact of environmental pollution.

Keywords: electrical energy management, energy efficiency technology, power factor correction, cost benefit analysis

1. Introduction

Tanzania is located in Eastern Africa, bordered by Kenya and Uganda in the North, Rwanda, Burundi and the Democratic Republic of Congo in the West, Zambia, Malawi and Mozambique in the South and the Indian Ocean in the Eastern part (www.tanzania.go.tz/economicsurveyf.html). It has land coverage of 945 749 km^2. Approximate 37.1 million people live in Tanzania, whereby about 70% of the population lives in rural areas (http:/www.tanzania.go.tz/population.html). The economical development of Tanzania mainly depends on agricultural production, industrial development and small business activities which largely depend on electrical energy. The power sector is managed by the Tanzania Electricity Supply Company (TANESCO). TANESCO is a solely Government owned company which has been given a mandate for generation, distribution and transmission of electricity.

For many years, electricity was generated from hydro, oil, coal and, to a minor extent, biomass and solar photovoltaic sources, but since 2004 it has been generated from natural gas as well [ESI Africa, 2006]. Hydro was predominantly a major sources of electrical energy in Tanzania. Due to the drought experienced in many parts of the country which reduced water levels in hydropower stations and consequently reduced generation capacity, the Government initiated via its utility company, a focus on expansion of non-hydro power sources such as natural gas and coal.

Energy management is a set of activities, which aim to reduce or shift electricity use so as to improve system reliability and manage electricity costs (Bjorke, 1986). However, in Tanzania, energy management (EM) has never been thought of as an alternative way for improving the performance of the utility industry, or to meet the energy demand of the country as it is done in other countries like South Africa. By the implementation of energy management, the utility company can save substantial energy which can defer the need for extending new power sources (Ming, 2006).

The aim of this paper is to analyze the potential area for electrical energy management in the industrial and commercial sectors, and highlight it as a challenge to the utility industry as well as to the end user. The comparison with the energy status of South Africa is also presented in this paper. The paper concentrates on energy efficient lighting, energy efficient motors, cogeneration and power factor improvement. Section 2 presents an overview of the power sector in Tanzania, section 3 shows the status of energy consumption, section 4 considers the type of commercial and industrial load, section 5 gives analysis and results, and section 6 the conclusions.

2. An overview of the power sector in Tanzania

Tanzania has abundant energy resources for power generation, but the energy situation is still characterized by low per capita consumption of commercial energy – petroleum, coal and electricity (MEM, 2003). In general, Tanzania depends largely on biomass fuel energy.

2.1 Available capacity of electricity generated

Hydro plants are important sources of electric power in Tanzania. They account for more than 55% of the total available capacity of the country. The remaining portion is contributed by thermal power plants. The total installed capacity is 1,027.3 MW. Figures 1 and 2 show the existing capacity of hydro and thermal power plants.

In comparison with generation and installed capacity of other SADC countries, e.g. South Africa of having a population of about 44.2 million people [Country analysis brief, 2007], their available capacity is 40,481MW [EIA, 2003], that is, Tanzania has about 2.5% of the installed capacity of South Africa. Table 1 shows generating and installed capacity of South Africa.

Table1: Generating and installed capacity of electrical energy in South Africa
Source: EIA (2003)

Plants	*Generation (billion kWh)*	*Available capacity (MW)*
Hydro	0.777	661
Nuclear	12.663	1 800
Geothermal and others	0.246	-
Thermal	202.24	38 020
Total	215.926	40 481

2.2 Load demand forecasting

Demand forecasts estimate the amount of electricity needed in the geographical area served by a power system. Demand forecast may project the amount of energy that will be needed over the course of the year(s). A demand forecast is a basic process for analyzing how much new generation capacity may be needed, which generation resources are applicable, as well as how transmission and distribution systems should be expanded.

As per (ESI Africa, 2006), Tanzania load demand forecast assumed that the Gross Domestic Product (GDP) will be 6%, while the electricity demand will grow at 10% to 12% per annum. In addition, it is assumed that there will be an increased capacity of mining and manufacturing industries. The forecasted generating expansion is shown in Table 2.

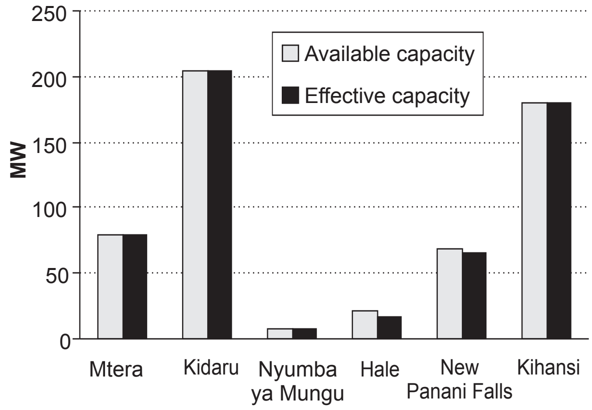

Figure 1: Capacity of hydropower plant
Source: TANESCO

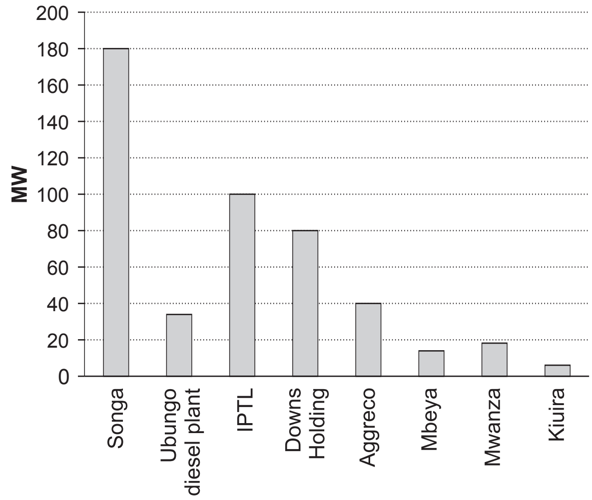

Figure 2: Capacity of thermal power plant
Source: TANESCO

Table 2: The forecasted generating plants expansion
Source: TANESCO

S/N	*Plant name*	*Capacity (MW)*	*Year*
1	Zambia interconnector	200	2010
2	Ruhudji	350	2016
3	Mchuchuma coal Phase I	200	2018
4	Mchuchuma coal Phase II	200	2022
5	Rumakali	222	2022

Based on the future expansion, there will be about five new installed generating stations from year 2010 to 2022, some of which are of natural gas and coal. The demand forecast of African countries in total is projected at 951 Billion kWh by the year 2030, with an average annual increase of 2.9% (International Energy Outlook, 2006).

South Africa is a big producer of electrical energy in Africa. Coal and oil are predominant energy resources in countries. These sources of energy have an adverse effect on the environment, resulting in environmental degradation. If electrical energy management is implemented properly, it may defer the need for installing the forecasted generating stations by the mentioned years. The power saved by implementation of energy management will be used to cater for the increasing demand.

3. Status of energy consumption in Tanzania

3.1 Overall energy consumption

The development process has proved that energy is one of the key ingredients of any growing economy and a key input to the operation of all sectors. The national energy demand (consumption) is estimated at 22 Million tones of oil equivalent (TOE) per annum or per capita energy consumption of 0.7 tones of oil equivalent (MEM, 2003), 90% of which comes from biomass and mainly used in the household sector; 8% from petroleum and gas, and 1.5% from electricity. The contribution of coal and other renewable sources is 0.5% (Mwihava and Mbise, 2005). While the total energy consumption of South Africa is 128.49 million TOE of which coal constitutes 75.4%, oil 20.1%, nuclear 2.8%, natural gas 1.6% and hydroelectricity is 0.1%, the per capita energy consumption of South Africa by year 2004 was 2.9 TOE (Country Analysis Briefs, 2007]). Figure 3 shows a summary of overall Tanzanian energy consumption by sector. The overall energy consumption by sector shows that the household sector constitutes a large share of the total energy consumption and most of them are non- commercial energy. This energy is mainly used for cooking, brewing, ironing and lighting. The main source of household energy includes fire wood, charcoal and biomass (agricultural residue and animal dung). These kinds of energy are easily accessed by the majority of low income earners.

3.2 Current electrical energy consumption

Electricity is the source of modern energy for economic activities. Currently, only 10% of the population has access to electricity supply, mainly those who live in urban areas (Mwihava and Mbise, 2005). The household, commercial and industrial sectors are the big consumers of electrical energy in Tanzania. Other energy consumers include electricity exported to Zanzibar Island, and public lighting. Figure 4 shows the proportion of electrical energy consumption in different sectors.

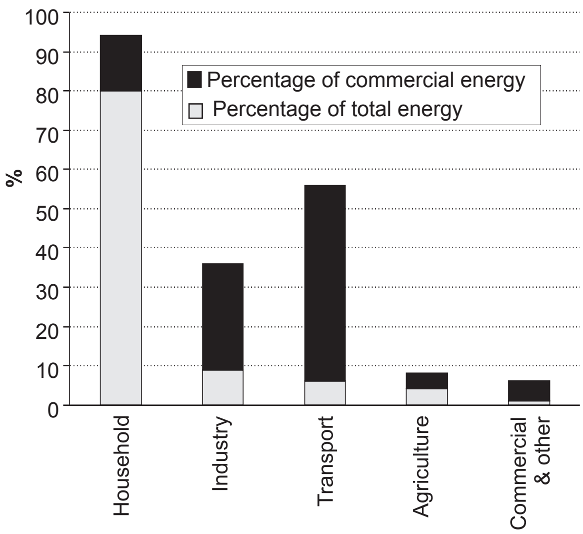

Figure 3: Energy consumption per sector
Source: MEM (2003)

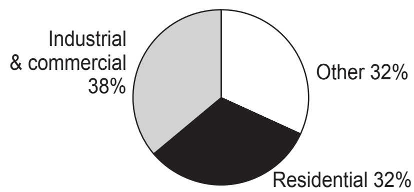

Figure 4: Electrical energy utilized per sector, 2005
Source: TANESCO

The pattern of electrical energy consumption per sector shows that the commercial and industrial sectors consume large amounts of energy compared to the household sector and the consumption trend has been rapidly increasing from 2002 to date, (Table 3). This calls for the need for implementation of electrical energy management in the industrial and commercial sector. The barrier for execution of energy management is a lack of skills and awareness among the end users of electrical energy, and, as a result, more energy is wasted.

The pattern of electricity generation and consumption in South Africa for the year 2003 was 215.926 Billion kWh and 198.842 Billion kWh respectively, and the loss was 15.115 Billion kWh, i.e. 7% of the generating capacity (EIA, 2003).

3.3 A need for energy management in Tanzania

There is a large population, increased urbanization and good industrial growth in Tanzania. The industrial sector grew by 9% in 2005 compared to 8.6 % in 2004 (www.tanzania.go.tz/economicsurveyf.html). The increase in industrial growth was mainly attributed to the increased production and mining indus-

Table 3: Overall pattern of electrical power generated and consumed from 1995–2005 (million kWh))
Source: TANESCO

Year	*Public lighting*	*Domestic*	*Commercial & industrial*	*Zanzibar Island*	*Total consumption*	*Transmission loss*	*Total power generated*
1995	11	660	876	84	**1631**	246	**1877**
1996	7	927	809	86	**1829**	193	**2022**
1997	3	1023	635	89	**1750**	222	**1972**
1998	8	1059	740	104	**1911**	253	**2164**
1999	2	1126	566	115	**1809**	516	**2325**
2000	2	1192	614	105	**1913**	571	**2484**
2001	4	1048	836	127	**2015**	727	**2742**
2002	0.1	1120	823	133	**2076.1**	714	**2790.1**
2003	0.2	1058	1190	145	**2393.2**	792	**3185.2**
2004	0.1	1162.7	1232.3	160.9	**2556**	840.5	**3396.5**
2005	0.03	1186.5	1312.7	185.6	**2684.83**	982.07	**3666.9**

tries. The growing urbanization is coupled with the increase of small industrial development (SIDO) and drives tremendous increase in commercial energy demands, which strain electrical supply systems.

Energy drives every economy of a country. The relationship between energy consumption and quality of life is shown in (Pastrnak, 2000 through the Human Development Index (HDI) against per capita energy consumption. It shows that the quality of life as measured by the HDI increases as per capita energy consumption increases. The HDI is a factor that uses life expectancy, education and GDP to measure quality of life. Industrial development needs a stable and reliable electrical supply for production stability. Hence, an energy management strategy is required to increase the efficiency of the existing supply systems by minimizing the consumption pattern while improving the quality of the energy services.

4. Type and characteristics of electric loads and their opportunity for energy management

Demand can be managed in two ways: either increase generating or manage load in demand / end user side. The industrial and commercial sectors consume about 36% of the total energy generated in Tanzania. Research on electrical energy management in this sector is of most importance for the benefit of the power supply industry and end user side.

4.1 Commercial sector

The combination of economic improvement, increases of private companies and including architecture have contributed to a widespread use of electrical energy. In this sector, electricity consumption has been rapidly growing due to increased use of air conditioners, interior lightings, lifts, office equipments and air handling equipments (Smith, 1978). Ultimately, due to increase in modern office machines and equipment, which encompass electronic controls and/ or circuits, when they are left on standby mode, consume some energy called standby power loss (Mohantry, 2001). Lack of monitoring and control mechanisms of switching off the lighting or air conditioning (A/C) systems after working hours, some light and A/C or fans are running idle and contribute to energy loss (Knisley, 1999).

Incandescent and fluorescent lamps are a widespread type of lighting used in this sector. The disadvantage of fluorescent lamps is their low power factor caused by inductive ballast while the disadvantage of incandescent lamps is its low efficiency and diminutive life. Therefore, energy management is a very important undertaking as it controls energy consumed in this sector.

4.2 Industrial sector

The electric motors are omnipresent of electrical equipment in the industrial sector. They account for a greater amount of total energy consumed in industrial plants. Induction motors are the most widely used motors in industries (Haward, 1982). The power factor (pf) of the induction motor is between 0.5 to 0.85 laggings. Therefore, the total power factor of the industries is diminished, usually ranging between 0.6- 0.75 lagging (Bhatia, 1983). The problems of Low pf are as follows

- Increase AC distributed cost
- Cause electromagnetic compatibility (EMC) environment due to high harmonics
- Increase unnecessary demand from the supply.

In addition to low Pf problems, the motor and its systems cause energy waste via the following:

- Improper selection of appropriate load with motor

- Low efficiency of the motor system
- Unmatched motors with drives causes high transmission loss which reduces the efficiency
- The use of traditional variable speed drives e.g. resistance methods
- Starting and running Idle of the production line

5. Cost benefit analysis of energy efficient technology

The cost benefit analysis is carried out for three promising technologies, i.e. energy efficient lighting, power factor correction and energy efficient motors. The market price for the equipment is the main source of financial data.

5.1 Commercial sector

The analysis is carried out considering energy efficient lighting. It is obvious that investment cost of energy efficient lighting is more than that of traditional lighting technologies but substantial energy saving and longer bulb life is realized. In this study, compact fluorescent lighting (CFL) is replaced by an incandescent lamp, fluorescent lamp T12 can be replaced by T8. Table 4 shows the comparison of costs of different types of lamps.

For minimization of running idle of the lighting, air conditioning and/ or fans, a motion sensor or occupation sensor can be installed in each office. In this analysis, the market price of the appliances and TANESCO electricity tariff is considered.

5.1.1 Lighting

Table 4: Comparison of cost of consumer investment of lamps

Comm. & industrial lighting	*Rating (W)*	*Operating hours/ year*	*Operating life (years)*	*Cost of lamps (R)*
Incandescent	100	2920	0.34	2.8
	60	2920	0.34	2.8
CFL	23	2920	5	78
	18	2920	5	78
T8 single	30	2920	5	184
T8 double	58	2920	5	

5.1.2 Study results for commercial lighting

From the end user perspective, one CFL saves the cost of about 15 incandescent lamps which is equivalent to R42 for 5 years. The investment cost for the CFL is R78, including insurance and service fees (www.eartheasy.com/live_energyeff_lighting.html) while the cost of fluorescent light is R184 [Http://www.lightbulbeporium.com/proddetail.asp]. Saving is calculated on the basis of saved electricity consumption multiplied by tariff for commercial entity. The cost of one kWh of electricity in the commercial sector is 1.10 R/ kWh (TANESCO, 2007). Replacement of a 60 W incandescent lamp with 18 W CFL will result in a saving of 42 W per lamp.

In this paper, the working hours are assumed to be eight hours per day. Therefore, there will be 2 920 hours per year.

The total energy saved by one 18 W and 23 W CFL is shown in Table 5, which is equivalent to the saving of R.675.00 per lamp. If the replacement could be done in a commercial entity with 10 000 lamps, the saving will be R 6.749.958 and R 12.362.958 for 18 W and 23W CFL respectively. The total kWh saved is 6.132 MWh and 23W is 11.242 MWh (for 5 years). The results show that, by the use of energy efficient lighting, the end user will benefit from purchasing less energy. The saved money can be utilized in other socio-economic development activities.

The kWh saved could be supplied to other consumers so as to increase the reliability and/ or to improve accessibility of electrical energy as well as to minimize environmental degradation. This paper analysed 18 W and 23 W CFL, in comparison to 60 W and 100 W incandescent lamps. More energy saving can be achieved by the replacement of other type of lamps like LED.

5.2 Industrial sector

The cost benefit analysis is considering power factor correction (pfc). This is assuming that the capacitor bank is used for power factor correction. The investment cost of capacitor bank (CB) is R.84.4 /kVAR, and operating and Maintenance cost R4.5/ kVAR/ year – 5% of investment cost (Yang, 2006).

The case study is considering a plant load of 1000 KW, which operates at 0.8 Pf lagging. If the power factor is improved to 0.95 lagging, assuming the plant operates 12 hours a day and 312 hours/ month (26 days per month), the total monthly kWh consumed is 312.000 kWh. Figure 5 and Table 6 show the influence of pf in a demand pattern.

Table 5: Analysis of energy saving potentials and demand reduction in lighting system

	CFL Ratings (W)	*Power saved (W)*	*Energy saved (MWh annual)*	*Energy saved for 5 years (MWh)*	*Saving of money for 5 years (R)*
Scenario 1,	18	42	0.122640	0.6132	675.00
1 lamp	23	77	0.22484	1.124	1 236.40
Scenario 2,	18	420 000	1 226.400	6 132	6 749 958
10 000 lamps	23	770 000	2 248.4	11 242	12 362 958

Table 6: Relationship between pfc and energy end use cost for improvement of pf from 0.8-0.95

Demand saving (kVAR)	*(kVA)*	*kWh charge / month (R)*	*Saved demand charge /month (R)*	*Cost of capacitor bank (R)*	*Maintenance and operating cost (R)*	*Life span (Years)*
429.3	197.4	110 000	7 600	36 215.7	1960	20

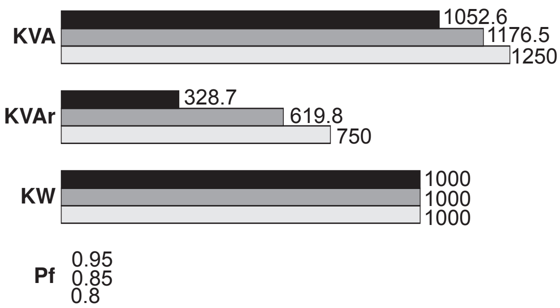

Figure 5: The pf and demand relationship

As per TANESCO Tariffs, (TANESCO, 2007), such a plant follows under tariff T3, High Voltage Maximum demand Tariff, and the monthly rate is shown in Table 7. This calculation excludes VAT.

Table 7: TANESCO tariff structure

Category	Monthly rate
Service charge R/ month	38.0
Demand charge R/ kVA	38.5
Energy charge R/ kWh	0.35

Table 8: Cost benefit analysis for power factor improvement

End user perspective	*1st year*	*2nd years*	*20th years*	*Payback period year*
Investment (R)	36 215.7	-	-	
Operating cost	-	1 906.1	1 906.1	
Saving for 12 months (R)	91 199	91 199	91 199	
Cash flow (R)	54 983	89 293	89 293x 18 years	0.41

5.2.1 Analysis of results for power factor correction

The results show that the pay back periods of installing a capacitor bank to end user is about 5 months. Therefore, the total saving of one plant for 20 years will be about R.1 751 550. If the power factor of many loads is improved, a substantial amount of money could be saved by the end users and the utility company can benefit on improving the reliability of electricity.

5.3 Energy efficient motors

Efficiency is an important factor to consider when buying or rewinding an electric motor. Improving the efficiency of electric motors and the equipment they drive can save energy and reduce operating costs. Energy-efficient motors use less energy. Because they are manufactured with higher quality materials and techniques, they usually have higher service factors and bearing lives, less waste heat output, and less vibration, all of which increase reliability. The cost effectiveness of energy-efficient motors depend on several factors, including motor price, efficiency rating, and annual operating hours of use, energy rates and cost of installation.

5.3.1 Motor size

Figure 6 shows that motor efficiency depends on the percentage of their loading. Motors should be sized to operate with a load factor of between 65% and 100%.

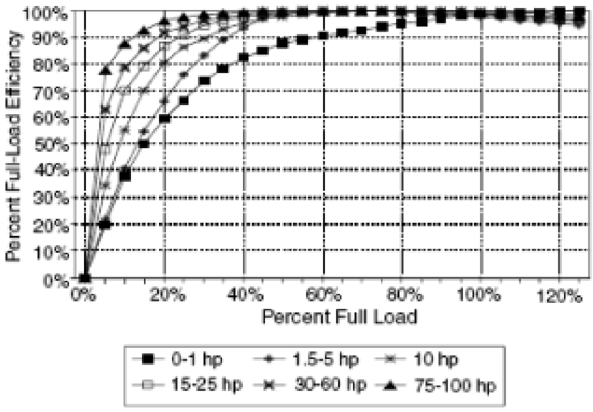

Figure 6: Relationship between motor load and efficiency

5.3 Cogeneration

Cogeneration is simultaneous production of heat energy and electrical or mechanical power from the same fuel in the same facility. Biomass refuses (bagasse) can be used for cogeneration energy production purposes. The benefit of the cogeneration is that, it increases efficiency, reduces and stabilizes energy cost and reduces greenhouse gas emissions. The use of cogeneration can minimize the stress of the supply system and change the consumption profile of the utility industry (Ariss, 2003).

6. Conclusion and recommendations

The paper shows how energy can be saved by the use of efficient lighting, energy efficient motors, and use of cogeneration in commercial and industrial sectors. The cost benefit analyses show, that if the traditional light is replaced with CFL or other high efficiency lighting, electrical energy could be saved. However, currently there is a paucity use of energy efficient lighting in both Tanzania industrial and commercial sectors. The use of power factor correction also provides savings of demand charge for the industrial customers or end user as it reduces the reactive energy flow in the system, which causes the TANESCO to charge extra (a penalty) for low power factor.

From the socio-economic point of view, the application of energy saving technology can enhance savings of a considerable amount of money. The utility industry will benefit from saving of energy as well as reduction of peak demand, which can minimize the race to construct a new power plant. The saved energy can be distributed to other consumers so as to improve reliability of electrical supply. The Government will benefit on the minimization of level of the environmental degradation. This paper highlighted a few techniques used for energy saving, but a greater amount of energy saving can be achieved if the energy stakeholders will put the emphasis on:

- Provision of regular awareness of the use of efficiency technology;
- Development of energy efficiency policy;
- Development and implemented demand side management program;
- Development of an energy efficiency standard for all equipment imported or manufactured inside or outside Tanzania; and
- Setting out on different mode of tariffs e.g. time of use.

Acknowledgements

The authors gratefully acknowledge the Energy Management Fund of the CPUT and TANESCO for their support and contribution of the data.

References

Ariss J, 2003, 'Biomass Cogeneration in Tanzania: Case study – Tanganyika Wattle Company' Paper presented in *East Africa Renewable Energy and Energy efficiency Partnership Regional Consultation Meeting*, 9th -10th June 2003.

Ashok S, 2006, 'Peak- load management in steel plants' *Applied energy* 83.

Bradley R. L and Fulmer R. W, 2004 'Energy conversion factor' [online] available www.instituteforenergyresearch.org/Energy_Conversion_Factors.htm.

Bhatia S.L, 1983, *Hand book of electrical energy*, Khanna Publishers, Delhi.

Bjork, C. O, 1986 'Analysis of industrial load management', *Proceedings of the American Power Conference*, Vol. 48, pp. 523-527.

Country Analysis Brief, 2007 'South Africa Energy Data, Statistics and analysis' [online] available from http://commercecan.ic.gc.ca/scdt (18/07/2007).

Energy efficient lighting [Online] available from www.eartheasy.com/live_energyeff_lighting.html (8/6/07).

Energy Information and Administration (EIA), 2003 'Country energy balance' online available from: www.eia.doe.gov/emeu/world/country/cntry_SF.html (18/07/2007).

ESI Africa, 2006, ''Power sector in Tanzania', an article prepared by TANESCO, Issue No. 2, [online] available from http://www.esi-africa.com/archieve/esi-content php (10/02/2007).

International Energy Outlook/ Energy Information and Administration, 2006 'World net electricity consumption by Region, Reference case, 1990-2030 [online] available from http://eia.doe.gov/cneaf/nuclear/forecast (18/7/07).

Jordan H.E, 1982, *Energy efficient electric motors and their application*, Van Norstrand Reinhold Publisher, New York.

Kinisley J. R, 1999,'Reducing high cost of electrical energy' [on line] available http://ceenews.com/mag/electric-reducing-high-cost/Index.html (12/3/07).

Ministry of Energy and Minerals (MEM), 2003, *National energy policy*, the United Republic of Tanzania.

Mohantry B, 2001 'Standby power loss in household electrical appliance and office equipment', Paper presented to *Regional symposium* on Energy efficiency standard and Labelling, 29-31 May 2001.

Mwihava N.C, Mbise H. A, 2005'Infrastructure and utilities as stimulants of economic development'. Paper presented in *annual engineer's day*, Karimjee Hall, Dar es Salaam.

Pasternak. A. D, 2000 'Global energy futures and human development: A framework for analysis' Report from U.S Department of Energy.

Smith, C. B, 1978, *Efficient electricity use*, 2nd edition, Pergamum Press, New York.

Tanzania National Electricity Company (TANESCO), 2007, 'Tariff' online available from www.tanesco.com/tariff .html (19/6/2007).

Tellus Institute of Boston Massachusetts, Best practice guide on integrated resource planning, Paper prepared for energy and environment training program, office of energy, environmental and technology, Washington, DC. Available online from www.goodcents.com/info/bestpractice (14/4/07).

United Republic of Tanzania, 'Country Profile' – Available online from www.tanzania.go.tz/economicsurvayf.html (12/3/07).

Wang X and Feng Z, 2003 'Energy consumption with sustainable development in Developing Country: a case in Jiangsu, China' *Energy Policy*, Vol. 31, pp 1679-1684.

Yang M., 2006, 'Demand side management in Nepal – , *Energy*, Vol. 31 pp 2341-2362.

Received 19 July 2007; revised 4 February 2008